# Permeable concrete for drainable pavement bases

Figure 1. Permeable concrete base courses contain few or no fines and a low cement content. They drain water readily, directing it to underdrains and preventing it from weakening underlying soils.

## Used to improve the performance of pavements placed over poor soils, permeable concrete is also a potential growth market for producers

By Carl A. Rapp

Permeable concrete is gaining acceptance for use as a pavement base course. As shown in Figure 1, this material produces a finished base course that is highly porous but stable. These properties produce three benefits:

- The material's drainable nature protects the primary pavement from harmful effects of surface and subsurface water.
- Strength and durability of permeable concrete provide a highly protective cover over the aggregate base and a strong working platform for placing concrete pavement.
- Ease of construction is a significant cost and scheduling factor.

The material can also be used for erosion control on side slopes and in paving ditches. In this usage it reduces runoff by allowing water percolation but still prevents soil erosion.

### Solving an airport soils problem

A longstanding problem at St. Louis-Lambert International Airport was recently solved by using this innovative concrete product. Because the airport was constructed on an old lake bed with silty, clayey, cohesive soils, drainage has always presented difficulties.

To prevent water from weakening these poor soils that lay beneath the airfield pavements, the portland cement concrete surface course was placed on a permeable concrete base course. This base course keeps ground water from affecting the pavement above it. And any water infiltrating pavement joints moves away from the pavement through the permeable concrete base to an underdrain system. The underdrains run along the edges of runways and taxiways and under the aprons. Placing this type of drainable base course results in an extremely strong, durable surface that provides the stabilized surface required by the Federal Aviation Administration's design criteria for heavy jet runways and taxiways.

At St. Louis-Lambert International Airport, three projects (in 1995, 1996 and 1997) utilized permeable concrete base courses. Our firm, CRD Campbell Inc., initiated the design of concrete base courses after experiencing problems with asphalt-treated permeable base. The required rolling temperature and variation of asphalt material in placement runs caused difficulty in obtaining consistent permeability and strength.

Figure 2 is an aerial view of Lambert Field showing areas in which permeable concrete was used. The material was first used on the main ramp in 1991, on the east apron in 1993, on the west airline ramp in 1995, then on the new Southwest Airlines apron and on acute angle exit taxiways serving a runway in 1996. In each case the permeable material was placed over a crushed-aggregate base course and directly beneath the concrete pavement.

Test results from compressive-strength cylinders indicated typical strengths ranging from 750 to 1000 psi in 28 days.

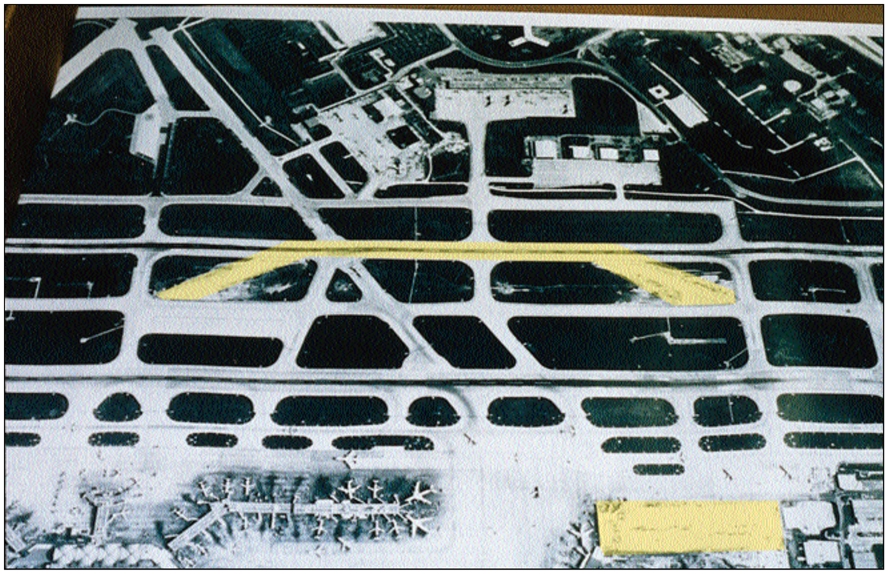

Figure 2. Highlighted areas in this overview of St. Louis-Lambert International Airport show areas where permeable concrete base was recently used.

## Specification requirements

The following descriptions of the material's composition and construction methods have been taken from a specification we developed for a number of FAA airport pavement projects.

Portland cement drainable base or permeable concrete consists of an open-graded material composed of mineral aggregate, portland cement and water mixed in a central mixing plant (or ready-mix trucks) and placed on a prepared course, usually a crushed aggregate subbase.

Material constituents are as follows:

- Coarse aggregate shall be ¾-inch maximum size consisting of crushed gravel or crushed stone and shall meet the requirements of ASTM C 33, Class 4S, and shall be ASTM C 33-90, Size 67. Also, the coarse aggregate shall meet the durability requirements for aggregate used in portland cement concrete.
- Fine aggregate shall consist of natural sand or manufactured sand meeting the requirements of ASTM C 33.
- Portland cement shall conform to the requirements of ASTM C 150, Type I. Substitution of fly ash or other pozzolans for portland cement will not be permitted for this material.
- Water used in mixing or curing shall be as clean and free of oil, salt, acid, alkali, sugar, vegetable or other substances that are injurious to the finished product as possible. Water known to be of potable quality may be used without testing.

The mix design for the permeable concrete is as follows:

- Cement content: 3 to 3.25 bags per cubic yard.
- Water-cement ratio: Approximately 0.36.
- Coarse aggregate: ASTM C 33-90 Size No. 67 (¾ inch to No. 4).
- Fine aggregate: Approximately 300 to 400 pounds per cubic yard.
- Coefficient of permeability (feet per day): 3,000 minimum. Test Method —ASTM D 2434-68 (Reapproved in 1974).
- Compressive strength: Proportions will be such to produce a compressive strength of 750 psi in 28 days as determined by test cylinders made in accordance with ASTM C 31 and tested in accordance with ASTM C 39. A strength of 500 psi will be required prior to any traffic being allowed on the surface. Test frequency will be 3 cylinders per placement day or 1 cylinder per 750 square yards.

The construction methods, equipment and tools used in placing permeable concrete differ significantly from those used in handling and placing portland cement concrete.

Figure 3. Permeable concrete bases are placed with equipment normally used for asphalt paving. For this work, the paving machine towed an additional vibratory plate to provide enough compaction to firmly seat the aggregate particles.

- Forms are not required as the material can support a standing edge during lane placement.
- Vibration (with normal concrete vibrators) is not required. A towed vibratory plate can be used, but vibratory drum rollers are prohibited.
- Preparation of the compacted subgrade or subbase to receive the cement-treated drainage layer is the same as that for normal portland cement concrete.
- Placing is performed using an AGB paver or equivalent. This paver provides adequate tamping and compacting effort in its lay down process so that very minimal or no additional compaction is necessary. Additional compaction, when required, must be initiated within 30 minutes of placing and strike-off operations and in general requires one to three passes of a 5- to 10-ton steel-wheel roller. Compaction seats the aggregate in a drainable base. In hard-to-access areas, hand-operated vibrating-plate compactors may be used to seat the aggregate.

The completed drainage layer must be cured with water for a period of eight hours following completion of compaction. Curing operations should begin within three hours after compaction and consist of fogging the surface of the drainage layer with a fine spray of water every two hours for the required eight-hour period. Apply the curing water so it doesn't erode the cement paste on the surface of the mixture. Application rate is approximately 2 gallons per minute.

Form all joints in a manner that ensures a continuous bond between old and new sections of the course. All joints should present the same texture and smoothness as other sections of the course.

## Delivery and placement

Figure 3 shows the placement of permeable concrete. It was delivered to the jobsite by dump truck, since the batch plant was close to the airport, but it can also be delivered by transit-mix trucks (see box). The permeable concrete was dumped into the placer equipped with a grade-controlling ski on the left side and a stringline control on the right side. The paving machine towed an additional vibratory plate that provided sufficient compaction to firmly seat the aggregate.

## Pavement design considerations

The thickness of the base course is determined by the load requirements for the finished pavement. The projects at St. Louis-Lambert International Airport normally required a 4- to 6- inch course of drainable base. A typical section for high-traffic areas used by large commercial jet aircraft consisted of a minimum of 6 inches of compacted subgrade, 8 inches of crushed aggregate base, 6 inches of drainable base, and 17 to 18 inches of concrete pavement. The pavement design included the underdrain system, which was composed of 6-inch perforated pipe placed about 2 to 4 feet below the subgrade in a porous backfill that was wrapped with geotextile fabric. The drainable layer was sloped to the underdrains, which were connected to the airport's existing storm drain system.

Permeable concrete drainable bases have been used effectively at the St. Louis-Lambert International Airport on projects costing a total of more than $15 million. Their usefulness and practicality have been proven, and the material will be continue to be used in a $2 billion Lambert expansion project. CRD Campbell Inc. has had extensive experience with permeable concrete and can provide further details upon request.

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## Clean mixer drum often when producing permeable concrete

Watch out for buildup when mixing permeable concrete, says Dave Graff, manager, Interface Materials of St. Louis. Interface has supplied the permeable base material for two of the Lambert Field projects, but it's not an easy job, according to Graff. The biggest potential problem is separation of the coarse aggregate from the small amount of mortar used in the mix. The mortar fraction sticks to the mixing drum walls and fins, compromising mix quality by preventing some of the coarse particles from bonding to the rest of the mass in the permeable base. And if the buildup of this low-water-cement-ratio mortar isn't cleaned off fairly often, workers may have to jackhammer out several cubic yards at the end of a production run.

Interface used a central-mix plant, hauling most of the material to the jobsite in dump trucks except for fill-in work where chute delivery with a transit-mix truck was required. "I would never try to dry batch the material into transit-mix trucks," says Graff, "because there's too great a danger of head packs developing."

With a central-mix plant, Graff says you can charge the material faster, helping to ensure better mixing and less coarse-aggregate separation. Even with central-plant mixing, however, buildup still occurs. On the airport job, six or seven lanes were usually completed during each production run, with each lane requiring about 125 to 150 cubic yards of material. When the contractor reached the end of each lane and had to reposition the paver, the short lull in production allowed Interface workers to remove buildup from the plant's mixer drum surfaces and fins before starting to mix material for the next lane. "If we hadn't done this," says Graff, "it would have been much harder to remove the buildup at the end of the production run. We learned the hard way that timely drum cleaning is essential."